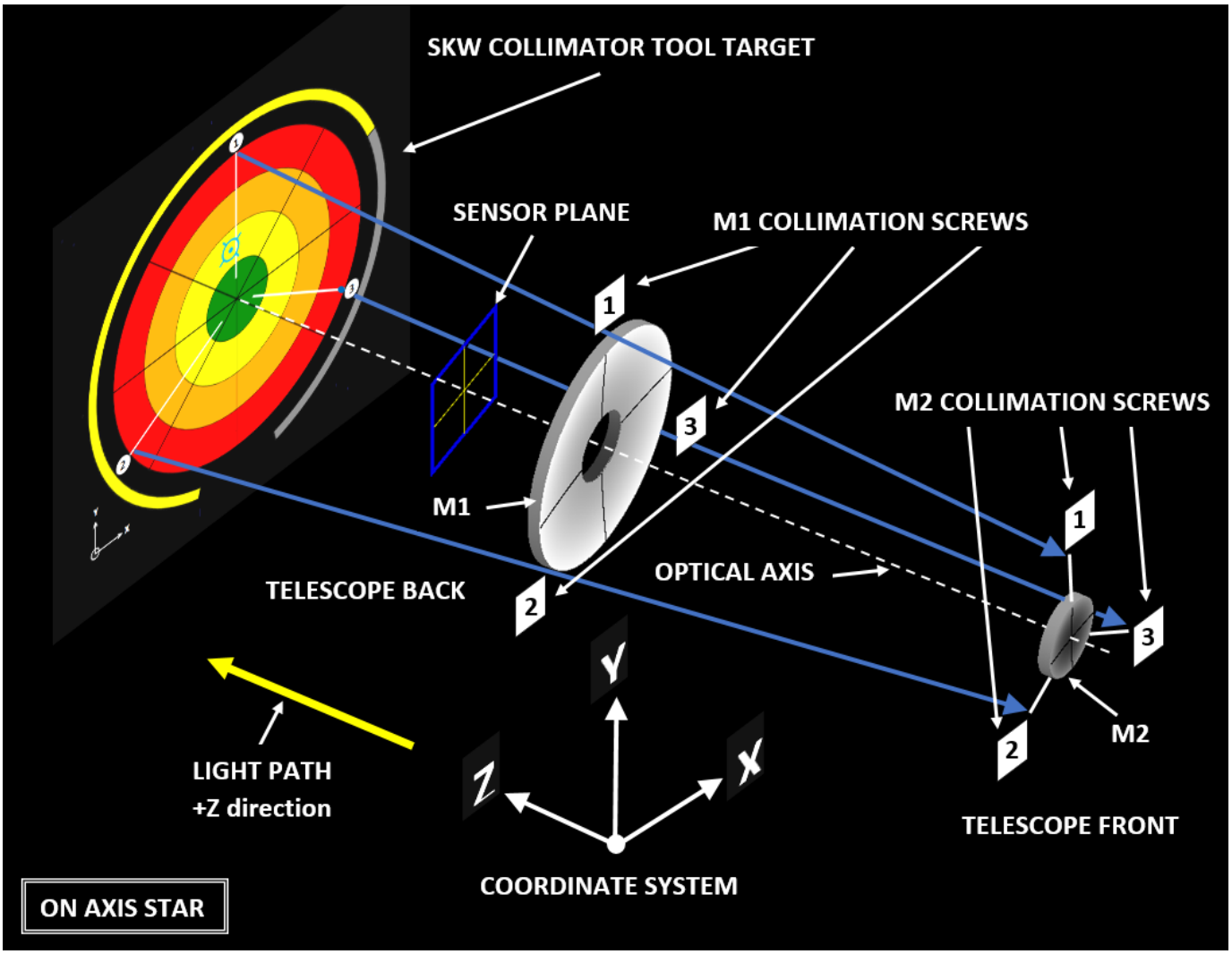
INNOVATIONS
FORESIGHT

SkyWave (SKW) Collimator Tool
Proper Set-Up for Telescope Alignment



Reference Diagram

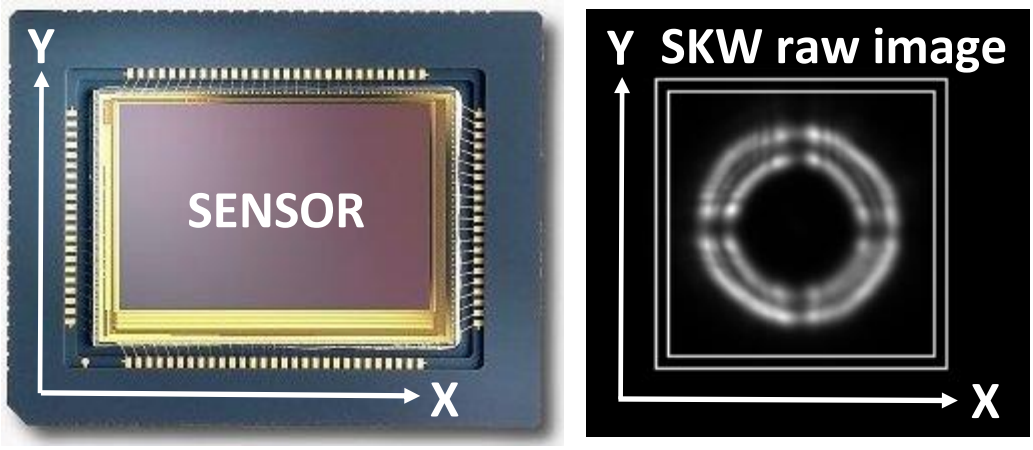
SKW uses the standard Cartesian coordinate system where the X axis is horizontal with the positive values on the right, and the Y

axis is vertical with the positive values on the top.
Therefore the images provided to SKW for processing should match this system in order for the collimation tool target to be correctly related to the telescope collimation screws, for either mirrors, during the alignment procedure using SKW.

Procedure for proper setup when using SKW:

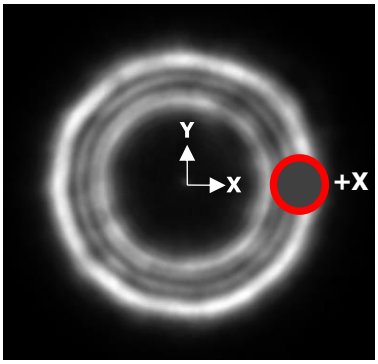
1. Looking from the front of the camera sensor, without the telescope, locate the X (horizonal) axis and check whether it is displayed from the left to the right in SKW raw image viewport. If inverted tick the SKW raw image "flip X" check box.
   Should you plan to use a star diagonal, an ONAG, a Newtonian telescope or alike, which optically inverts the X axis then you should also flip X in SKW.

2. Looking from the front of the camera sensor, without the telescope, locate the Y (vertical) axis and check whether it is displayed from the bottom to the top in SKW raw image viewport. If inverted tick the SKW raw image "flip Y" check box.
   Many acquisition programs under Windows OS may inverse the Y axis, its origin being then on the top of the image. In such cases you will have to invert the Y axis on SKW using the "flip Y" check box.
   Should you plan to use a star diagonal, an ONAG, a Newtonian telescope or alike, which optically inverts the Y axis then you should also flip Y in SKW.



Sensor and SKW coordinate systems match

3. Assuming you have completed the points 1 and 2 above, center a bright star in the camera, defocus it either extra (after the focal plane) or intra (before the focal plane) focal until you can clearly see the defocused star diffraction pattern. Then place a finger, or an opaque object such as a pen, along the edge of the front cell of the telescope pointing towards the center of the secondary mirror (M2) mount. The shadow of this obstruction should be visible when looking at the out of focus diffraction pattern image. Rotate your finger, or the opaque object, around the tube edge until its shadow is located at the right (the most positive X value) of the defocused star image.

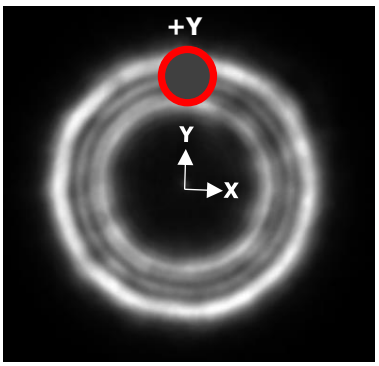


Shadow at +X

If you are defocused intra focal using a sticker, or similar means, label at the position of your finger, or opaque object, this location on the edge of the front cell of the telescope as "+X".
If you are defocused extra focal label the opposite side, 180 degrees away, instead.
You now have established the relationship between SKW coordinate system and the telescope for the X axis.
It is important to understand that, when facing the front of the telescope, this "+X" label may not be on the right or even oriented horizontally, this is normal. It all depends on the rotation of the camera relative to the telescope optics, see an example below.

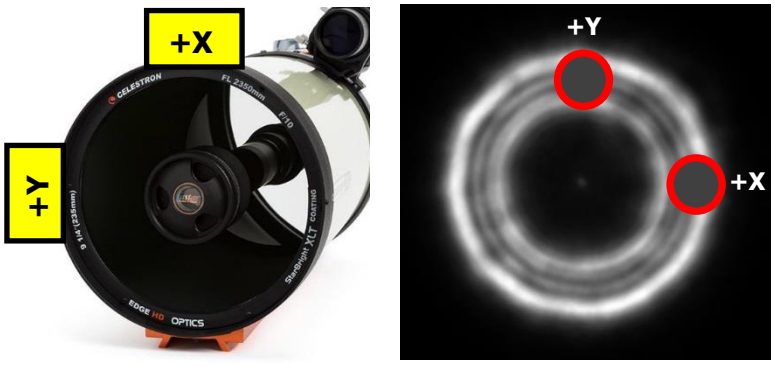
Example of a possible "+X" labeling and related shadow.
Here the label is located at the top of the OTA due to a 90 degrees anti-clockwise rotation of the camera X axis.

4. Now rotate your finger, or the opaque object, around the tube edge until its shadow is located at the top (the most positive Y value) of the defocused star image.



Shadow at +Y

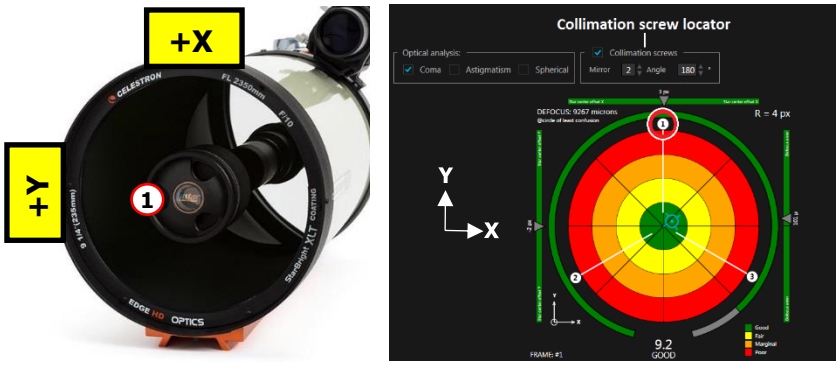
If you are defocused intra focal using a sticker, or similar means, label at the position of your finger, or opaque object, this location on the edge of the front cell of the telescope as "+Y".
If you are defocused extra focal label the opposite side, 180 degrees away, instead.
You now have established the relationship between SKW coordinate system and the telescope for both X and Y axes. As for the X axis is important to understand that, when facing the front of the telescope, this "+Y" label may not be on the top or even oriented vertically as well, see an example below.



Example of possible "+X" and "+Y" labeling and related shadows.

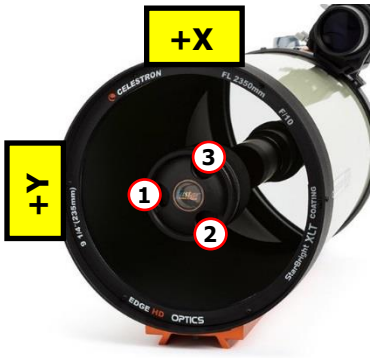
5. Sanity check:
   The "+X" label location should be located 90 degrees clockwise from the "+Y" label location.

6. Locate the M2 collimation screw the closet to either labels. If you do not have any M2 collimation screw then use the M1 screws instead. Label it as "1".
   In SKW collimator tool using the collimation screw locator feature, select M2 (or M1), and rotate it until the screw labeled #1 is correctly oriented in relation of the X and Y axes and labels, see below an example.



Collimation screw #1 location relative to the telescope labels and to the SKW collimation screw locator for M2.

7. Label the collimation screws #2 and #3 accordingly to their positions on the SKW collimation screw locator and SKW collimator tool coordinate system, see example below.



Collimation screw locations relative to the telescope labels and to the SKW collimation screw locator for M2.

8. Repeat the operation for the collimation screws of the other mirror (M1 or M2) if applicable.

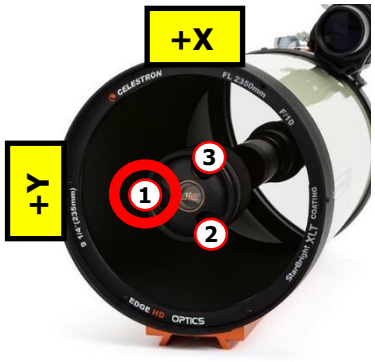
Alignment (for congruence) of Cassegrain type of telescopes with at least one spherical mirror, such as SCT, CDK, iDK, …, using SKW collimator tool:

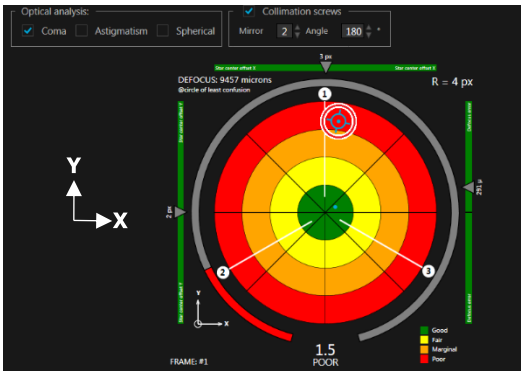
After having performed the above procedure successfully you are now ready to align (aka collimate) your scope with SKW.

The alignment of both mirror optical axes, known as congruence (making both axes superimposed), for this type of telescope is done by canceling on-axis coma only, therefore you should select coma only on the SKW collimator tool.

Alignment is done by using the M2 collimation screw (tilt/tip corrections of the mirror), or for some telescope, such most Maksutov Cassegrain models, the M1 screws.
Only one mirror needs to be aligned, the other remains in place.

- Rule:
  Pull M2 (or M1) at the position indicated by the SKW score mark angular direction in the SKW collimation tool using the SKW X, Y axes, the collimation screw locator information and the labels.





Example, using the axes and collimation screws labeled previously, of a vertical alignment induced coma and its corrective action from SKW collimator information.
M2 needs to be pull at the location of the screw #1.
For most telescope M2 mount collimation tilt/tip adjustment mechanisms this means tightening of the screw #1.

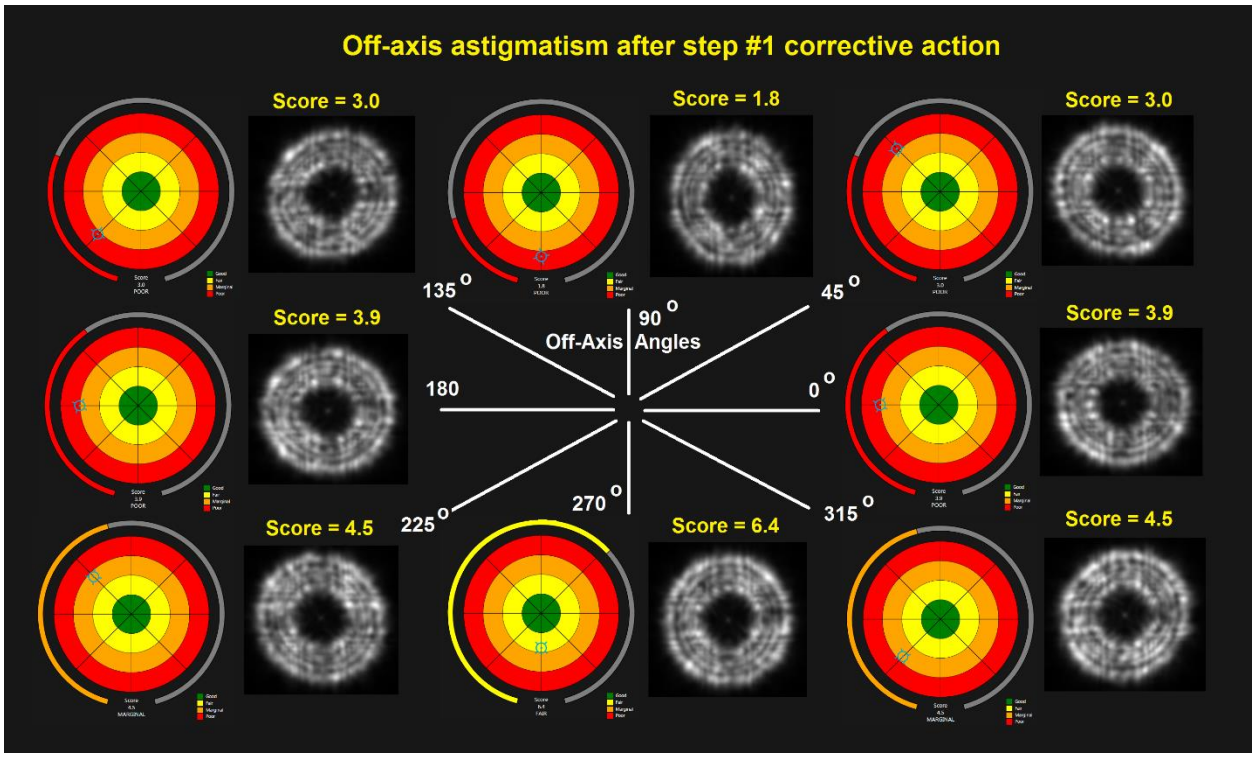
- **Alignment (for congruence) of a Ritchey–Chrétien telescope (RCT), using SKW collimator tool:**

  The alignment of an RCT is more complex since both mirrors are aspherical.
  Both M1 and M2 tilt/tip adjustments are necessary for reaching congruence.
  Failing to follow the proper alignment procedure leads to an

ever-increasing off-axis astigmatism <u>even in the absence of coma</u>.

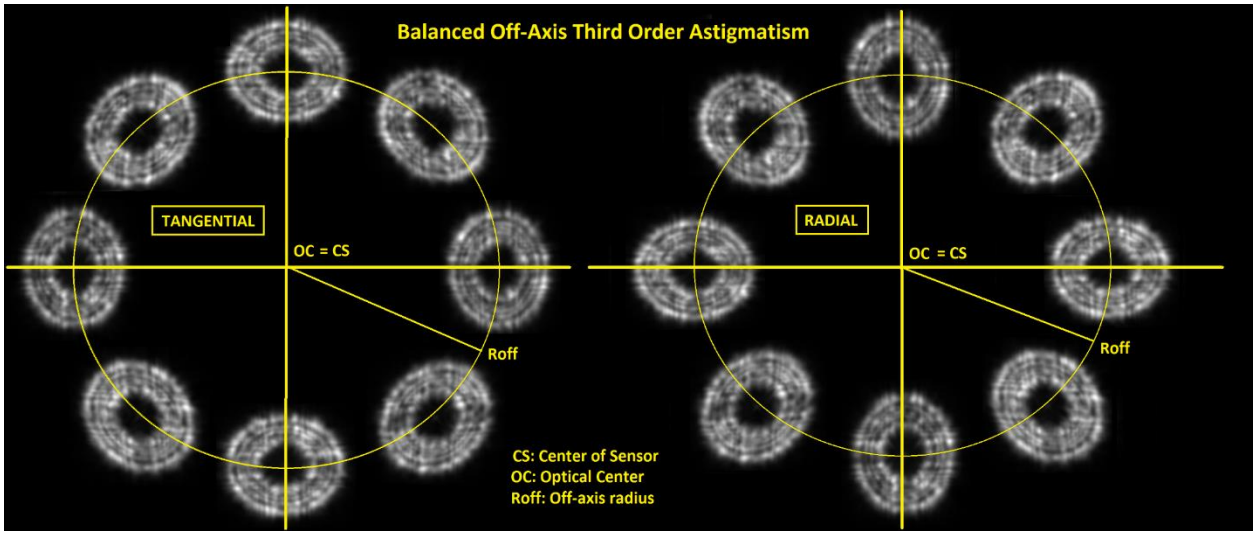
- Step #1: Adjusting (tilt/tip) **M1** only to remove on-axis coma. Using the same rule than described above in the context of Cassegrain type of telescope having at least one spherical mirror. But this time it is paramount to use only **M1** for this task, never **M2**. Select <u>coma only</u> on the SKG collimator tool.

- Step #2: Adjusting (tilt/tip) **M2** only to balance off-axis astigmatism.
  Use and analyze with SKW stars at a given constant off-axis radius (+/-10%). <u>Astigmatism only</u> should be selected. See an example below.



Example of 8 off-axis defocused stars at near identical radii with their related SKG collimator scores. Here the off-axis astigmatism is unbalanced. The scope need alignment.

- Rule:
  Pull M2, only, at the angular position indicated by the lowest SKW collimator tool score using the SKW X, Y axes, the collimation screw locator information and the labels. In the above example it would be at +Y.



Examples of successful tangential and radial balanced off-axis astigmatism at a constant off-axis radius Roff.

Then repeat step #1 and #2, in this order, until the on-axis coma is removed, and the off-axis astigmatism is balanced. Convergence takes usually 2 to 3 iterations.

Dr. Gaston Baudat